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Simulation of Grass Land

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Simulation of Grass Land Distribution in North Carolina

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Outline

- Motivation of our research in modeling the grass land coverage in NC
- Introduction to computer modeling of ecosystem changes
- Model descriptions
- Experiment: Simulation and classification
- Simulation Results and discussion
- Conclusion

Motivation

- BRAC (Base Realignment and Closure Act, 2005): will relocate about 25,000 to 30,000 persons to Fort Bragg by 2011
- Environmental sustainability is a concern; It is valuable to understand the effects of changes a military base will bring about so that necessary actions will be taken to protect the environment.
- Environmental study: Ecological modeling is an active research aiming to interpret and acknowledge or to predict natural environmental changes using simulated data
- Previous research experience on image modeling

Introduction

Existing research on modeling ecosystem

- To interpret or to predict natural environmental changes using simulated data

Dale, V. H. and Beyeler, S.C. “Challenges in the development and use of ecological indicators”. Ecological Indicators, No. 1: pp. 3-10, 2001.

- To predict ecosystem recovery at military bases

Garten, C. T. and Ashwood, T.L. “Modeling soil quality thresholds to ecosystem recovery at Fort Benning, GA, USA”. Ecological Engineering, No. 23: pp. 351-369, 2004.

Goals

- Using the empirical Bayesian approaches for modeling the status of an area grass land coverage with interactions with neighboring area's development
- Use the simulation data to predict the natural environmental changes due to increased population density
- Address the uncertainty of natural disturbances associated with the ecological situations

Simulation Techniques

Monte Carlo Markov Chains (MCMC) simulation technique: Gibbs sampling approach is used to simulate the grass land distributions

Method

Specifications

- The coverage of grass land is described by the percentage, which is viewed as coming from a random field
- The status of grass land coverage for the *i*-th county in NC takes an integer value from 0-100, and is denoted as x_i
- Effects of population density and the effects from neighboring regions are considered

Model:

The grass land coverage for each county follows a Poisson distribution

$$x_i \sim Poission(\mu_i)$$

where μ_i is the mean value of the grass land coverage of the i-th county

We wish to make inference of μ_i

$$\log(\mu_i)\big|\theta_i, \lambda_{ij} = \alpha f(\theta_i) + b_i$$

θ_i The effects from the density of residential population in i-th county

λ_{ij} The effects from the *j*-th neighboring region grass land coverage on the *i*-th region (county).

b_i A spatial random effect in i-th county by considering all the effects coming from the grass coverage of all its neighboring regions λ_{ij}

α A small valued random parameter that puts weights on $f(\theta_i)$

The random effect parameter, b_i , $i=1, 2, \ldots, N$

follows a multivariate Gaussian distribution using the Conditional Autoregressive (CAR) prior model. The joint spatial Gaussian distribution of b_i is described as:

$$(b_1, b_2, \cdots, b_N) \sim N(\mu_b, M)$$

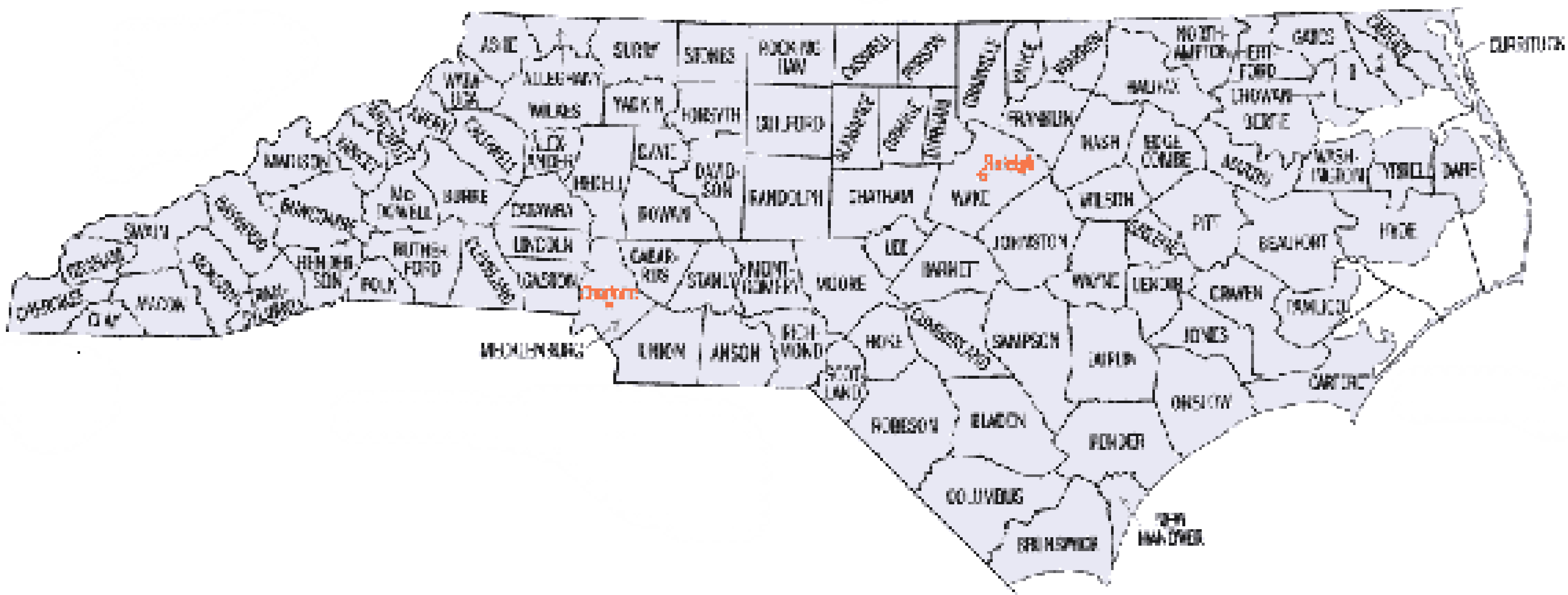
μ_b : a 1xN mean value vector and is balanced by on the average grass land coverage of neighboring regions and the region being considered.

M : a NxN positive definite covariance matrix that takes into consideration of the effects from the status of neighboring grass land coverage, λ_{ij}

Experiment: Simulation

Simulation Steps

1. First of all, a NC county map was obtained, from which, the boundary of each county was identified (100 counties in total) as shown in Fig. 1.

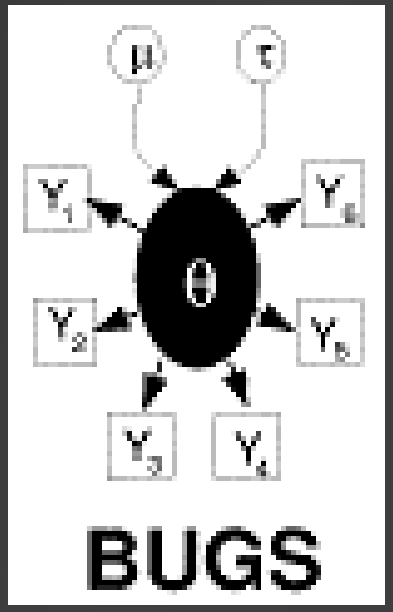


Simulation Steps (Continued)

2. For simplicity, only 21 counties to the west part of NC were selected for simulation.
3. For each county where the percentage of coverage is to be simulated, the neighboring counties associated with it were identified (varied number of neighbors for each county)
4. The current grass land coverage of each county was evaluated. This was roughly estimated using a satellite image downloaded from Google map website.
5. The grass land coverage of each county was simulated using MCMC, and is used as a new grass land coverage that we are looking for.

Software used for simulation

- WinBUGS software was used
  - publicly available
  - for Bayesian analysis using Markov chain Monte Carlo methods
- http://www.winbugs-development.org.uk/



- The parameters needed are initialized.
- In each iteration, the mean value of the status of coverage, and spatial random effects were alternately simulated from their distributions for every county.
- The simulation was updated for 50,000 iterations
- For every county, the mean was calculated and was used as the updated status of the grass land coverage.
- The simulated statuses were classify to 10 different levels by scaling the percentage of coverage, and different classes were shown in a map.

Results

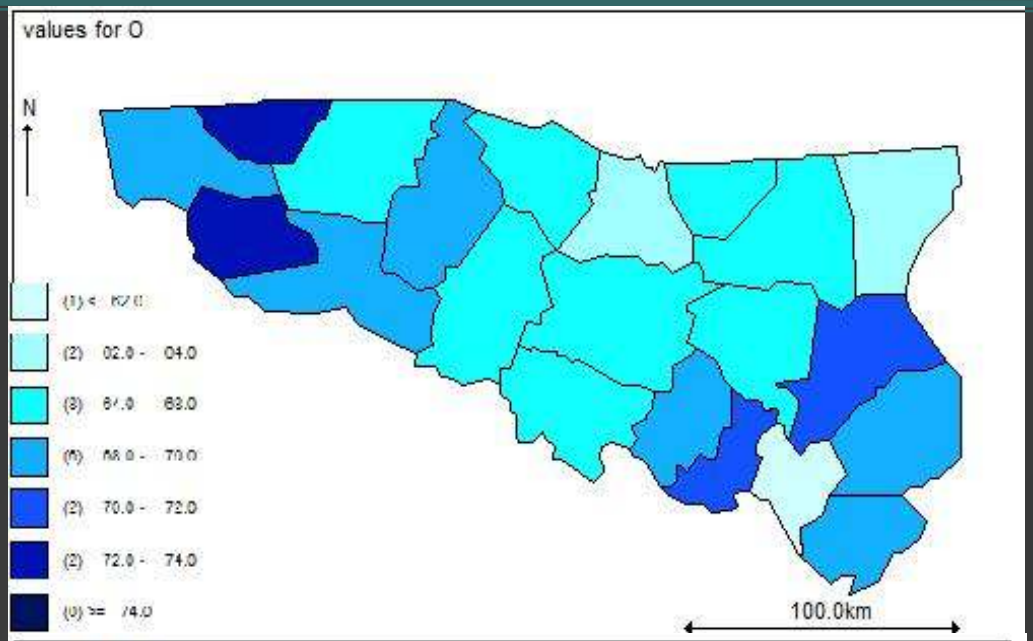


Figure 2. Observed grass land coverage is shown.

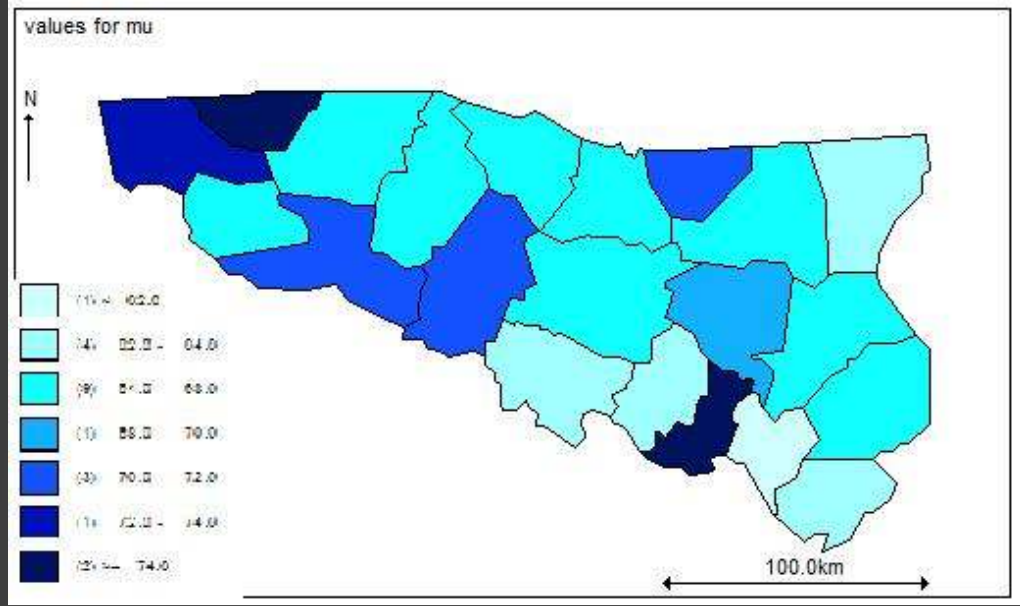


Figure 3. The estimated grass land coverage for a new time period (second year) is shown

Discussion

Compared Fig. 3 to Fig.2

- Less grass land coverage is observed in some areas
- Heavier grass land coverage is observed in some areas
- Over all, no large changes of the grass land coverage are seen. This is because the observed data is used as prior knowledge
- Simulation results are sensible to the choice of parameters.

Conclusion

- we have used the MCMC approach to simulate the grass land coverage, where the random effects from neighboring regions were considered
- The Gibbs sampling technique is used.

Future Research Interests

- Simulate the grass land coverage of smaller areas, such as local communities
- Elaborate the neighboring effects in the simulation model
- Elaborate the value of effects on the grassland coverage
- Control the simulation errors

THANK YOU !!!